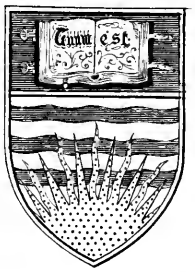

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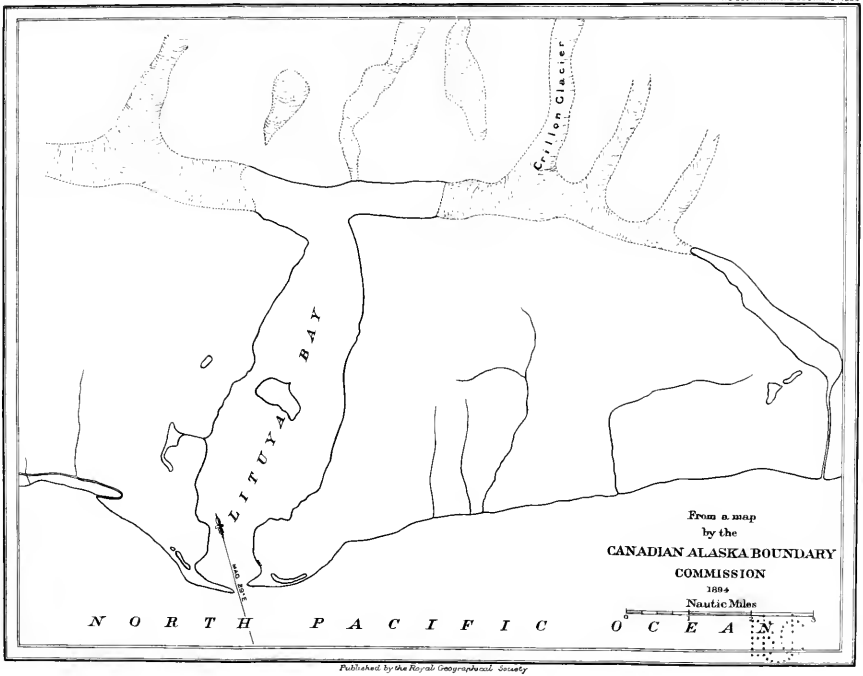

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NOTES ON GLACIERS OF SOUTH-EASTERN ALASKA AND ADJOINING TERRITORY.*

By OTTO J. KLOTZ, Canadian Topographical Survey.

THE writer first visited South-Eastern Alaska in 1889, and spent the seasons of 1893 and 1894, with a steamer at his disposal, along the continental shore-line, in connection with the International Boundary Survey. These notes are, therefore, incidental to other work.

In 1894 a photo-topographic survey was made of the front of the Baird glacier for the study of its motion. The results were published in the *Journal of Geology*, vol. iii. No. 5 (1895), and may be briefly summarized :—

Photographs (photo-topographic camera) taken May 15, 19, July 13, and August 11; base-line, 850 feet, about 1700 feet from glacier, which has a frontage of a mile. Between July 13 and August 11 the end of the Baird glacier was lowered by melting a little over 2 feet, and the average motion of the ice in that part was 1 foot per day. The slope was 1 : 3; the slope of the glacier itself for 15 miles in a straight line is 1 : 20, or nearly 3°. The mean slope of the Patterson glacier, lying south-east of the Baird, is in 10 miles, 1 : 13, or 4° 25′.

The Canadian International Boundary work covers the land area—some 14,000 square miles—adjoining the continental shore-line from Mount St. Elias to Portland canal, and is delineated on twenty-four sheets of 1°—latitude and longitude—contour-lines 250 feet intervals; scale 1 : 160,000, besides one covering the whole on a scale of 1 : 960,000. The topography—contour-lines—is based solely on the camera, and, as such, is the largest photo-topographic survey made anywhere.

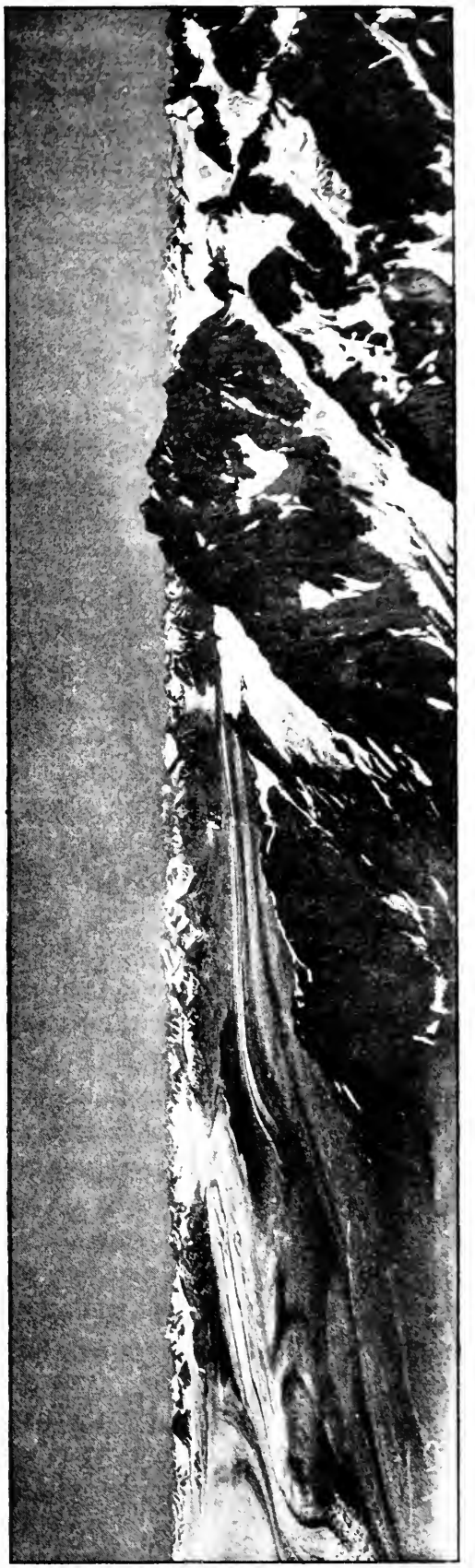
* Maps, p. 592.

The following notes are based on a comparison between the surveys of La Perouse and Vancouver and ours (1893).

The scientific expedition of La Perouse made a lengthened stay with the *Boussole* and *Astrolabe* during July, 1786, in Lituya bay, making at the time a detailed survey of the T-shaped arm, a chart of which on a large scale (1 inch = four-fifths statute mile) is given in his atlas, and is here reproduced, together with one for the same bay enlarged to the same scale from our 1 : 160,000 sheet. Before making a comparison, La Perouse's description of the bay will be given ('Voyage Round the World,' vol. ii. pp. 85–87).

"To form an idea of it, it is necessary to conceive a basin of water, unfathomable in the middle, bordered by peaked mountains of great height, covered with snow, and without one blade of grass to decorate this vast heap of rocks, condemned by nature to eternal sterility. I never beheld the surface of the water ruffled by a single breath of wind. Nothing disturbs it but the fall of enormous masses of ice, which frequently separate from five different glaciers, while the sound is re-echoed by the distant mountains. The air is so calm, the single voice of a man may be heard half a league, as may the cries of a few sea-fowl, which deposit their eggs in the hollows of the rocks. It was at the head of this bay that we hoped to find channels by which we might penetrate into the interior of America. We conjectured it might lead to some large river, taking its course between two of the mountains, and originating from one of the great lakes north of Canada. Such was our chimerical notion, and this was its result. We set off in the two large barges of the *Boussole* and *Astrolabe*. Messrs. de Monti, de Marchainville, de Boutervilliers, and Father Receveur accompanied M. de Langle, and Messrs. Dagelet, Boutin, Saint-Ceran, Duche, and Prevost were with me. We entered the channel on the west. Prudence required us to keep some distance from the shore on account of the falling ice and stones. At length, after having rowed a league and a half-mile, we found the channel terminated at two vast glaciers. We were obliged to push away the flakes of ice with which the sea was covered to penetrate thus far, and the water was so deep that I could find no bottom at half a cable's length from the shore with a line of 120 fathoms. Messrs. de Langle, de Monti, and Dagelet, with several other officers, attempted to ascend the glacier. With unspeakable fatigue they advanced 2 leagues, being obliged at extreme risk of life to leap over clefts of great depth; but they could only perceive one continued mass of ice and snow, of which the summit of Mount Fair-weather must have been the termination. . . . I had sent M. de Monneron and M. Bernizet to explore the eastern channel, which terminated like this, at two glaciers. Both these channels were surveyed, and laid down in the plan of the bay."

With reference to the two accompanying charts of Lituya bay, few



PANORAMA OF MUIR GLACIER.

words are necessary, as they speak for themselves. La Perouse's is from a hydrographic survey; the Canadian from a topographic survey, and the two are fairly accordant.

It will be seen that the two large glaciers of the northerly arm are now united, and have advanced into the arm fully 3 miles, and into water where La Perouse failed to find bottom at 120 fathoms. Similarly, the glaciers of the southerly arm have united and advanced about $2\frac{1}{2}$ miles. These distances represent the sum of the fluctuations during the century. Of the fluctuations themselves we at present know nothing. On La Perouse's chart will be seen a small glacier near the middle of the northerly arm and reaching to the water; on the recent chart this glacier is still shown, but as having receded from the water's edge. We have, therefore, the apparent anomaly of advance and recession of glaciers side by side. Perhaps not too much weight should be given to La Perouse's sketching (to the water's edge) of this small glacier. However, the proof of the advancement of the large glaciers is incontrovertible. It is not the intention, in the present paper, to enter into a discussion of the climatic or other reasons that brought about this change, but simply to state facts.

Leaving now Lituya bay and proceeding some 45 miles south-easterly, we come to Cape Spencer, from which point Mr. Whidbey, under Vancouver's direction, made a connected survey of the continental shore-line along Cross sound, Lynn canal, Stephen's passage, and Frederick sound to the muddy waters of the Stikine. For the purpose of this paper, the most interesting part of this survey is from Cape Spencer to the vicinity of Point Carolus. I have plotted his courses through this interval, and am satisfied of their accuracy by comparison with our survey.

Let me quote from Vancouver (vol. v. pp. 416, 417): "He (Whidbey) commenced on the forenoon of the 10th (July, 1794) from Cape Spencer, with very thick, foggy weather; this inconvenience, in addition to the immense numbers of huge pieces of floating ice, very much retarded his progress across the sound. Having at length effected this object, the continental shore from the cape above mentioned was found to take nearly a north direction for about three leagues to a low pebbly point; north-north-west from which, 5 miles further, a small brook flowed into the sound, and on its northern side stood the ruins of a deserted Indian village. To reach this station, the party had advanced up an arm about 6 miles wide at its entrance, but which had decreased to about half that width, and there further progress was now stopped by an immense body of compact perpendicular ice, extending from shore to shore, and connected with a range of lofty mountains that formed the head of the arm, and, as it were, gave support to this body of ice on each side. Their course was now directed across the arm and on its eastern side; compelled by the inclemency of the weather, the party stopped until it should prove more favourable to their purpose. These

PANORAMA OF JOHNS HOPKINS GLACIER.

shores are composed of a border of low land, which on high tides is overflown and becomes broken into islands."

Although in this description Vancouver does not state how far the ice-front was above the "small brook" or "deserted Indian village," yet, in his further description of the next inlet or arm east of Point Wimbledon (now known as Dundas bay), we find, p. 419: "Beyond them (islets and rocks) on the western shore was a small shallow opening that appeared to communicate with one of a similar description, and which had been noticed in the other arm (Taylor bay as now known) a few miles below the icy barrier, but was too shallow to be approached by the boats."

This, then, gives us a pretty fair idea of where the ice-front was in Taylor bay. I have designated by A (see chart) the "shallow opening" in Dundas bay, and by B the one in Taylor bay referred to, and likewise have plotted the position of the "small brook," "deserted village," and ice-front. The main fact elicited is that the glacier (now known as the Brady) has advanced over 5 miles. Furthermore, the "deserted Indian village" is now covered by nearly 1000 feet of ice; similarly, the brook and, besides, the waters flowing from that part of the glacier now flow westward into the Pacific instead of southerly. An examination of the chart furnished the explanation. This advancement within exactly one hundred years is large; the burying of the village under so vast a load of ice adds interest to this glacial motion, which, however, is far eclipsed by the phenomenon of opposite character—recession—in the neighbouring Glacier bay.

Let us again quote Vancouver (p. 421) for the description of that which is now designated as Glacier bay: From "Point Dundas, situated in lat. 58° 21′, long. 224° 1′, the coast takes an irregular east-north-east direction about 7 miles to a point. . . . To the north and east of this point the shores of the continent form two large open bays, which were terminated by compact solid mountains of ice, rising perpendicularly from the water's edge, and bounded to the north by a continuation of the united lofty frozen mountains that extend eastward from Mount Fairweather. In these bays also were great quantities of broken ice, which, having been put in motion by the springing up of a northerly wind, was drifted to the southward, and, forcing the boats from the northern shore, obliged them to take shelter around the north-east point of the above island" (Lemesurier).

From Vancouver's measurement, it would appear that the point now known as Point Carolus has either emerged or advanced eastward since his time. The main fact, however, is the position and limit of the "two large open bays." From his chart (not given here) they are shown as less than half the depth of the arm adjoining Cape Spencer, *i.e.* about 5 miles. There is no doubt in my mind about the accuracy of the position given of the ice-front at that time, and that there was practically no

Glacier bay save the relatively small indentations compared with the present bay.

Referring to the chart of 1894, it will be seen that the ice-front of 1794 has receded upwards of 45 miles in a north-westerly direction, and that part, so well-known as the Muir glacier, has receded 25 miles. The latter glacier has been fully described by Prof. John Muir, Prof. G. F. Wright in *American Journal of Science* for January, 1887, and also by Prof. Harry Fielding Reid in the *National Geographic Magazine*, vol. iv., March, 1892. Willoughby island, with an elevation of 1545 feet, gives

LOOKING WESTERLY, JOHNS HOPKINS GLACIER TO RIGHT.

ample evidence of having been entirely covered with ice recently, and the ice-markings on mountains adjoining the eastern (1894) terminal of the Muir glacier are at an altitude of about 2500 feet, from which we obtain the maximum slope of the glacier between those points to have been 32′, which is very small compared with those given for the Baird and Patterson. However, even at that small angle of incline we would find the depth of the glacier to be 3400 feet where now the Grand Pacific and Johns Hopkins glaciers discharge into this bay. From that point of elevation it seems probable that the ice would seek the shorter route to the sea and move towards Taylor bay, into which now the Brady glacier discharges. At the present time the ice over this stretch moves in both directions, one south into Taylor bay, the other north into the north-west arm of Glacier bay. A future examination of the ice-markings below the 4000-foot level on the rocks south of the above

north-west arm will definitely settle the direction of the former ice-flow there.

From the preceding we see, therefore, that we have two ice-streams, whose mouths are within 20 miles of each other; the one has receded within a hundred years fully 45 miles, while the other has advanced over 5 miles. Abut this the proofs seem absolutely conclusive.

Of the other glaciers along the continental shore-line, eastward from Glacier bay as far as the Stikine, we have no survey or measurement by Vancouver (or any one else) to enable us to make comparisons with their present position, and for that purpose must rely simply on his general description of them. Reading Vancouver carefully, and from the writer's intimate knowledge of that continental shore-line, I think I am correct in saying that in that latter region all the glaciers have receded since the days of that illustrious explorer.

It seems somewhat strange that Vancouver does not mention what is now known as the Davidson glacier; although, in passing close in-shore, the woods on the terminal moraine may have hidden it, yet he must have seen it from the opposite shore afterwards.

As the works of Vancouver are probably not very accessible, and for future reference, it is considered desirable to quote some extracts pertaining to glaciers.

Of the head of Chilkat inlet, Lynn canal, at the mouth of the Chilkat river, we find (p. 426, July, 1794), "It was here remarked that, notwithstanding the quantity of fresh water which flowed into this arm from the brook just mentioned, the shores were perfectly free from ice, although they were three-fourths of a degree to the north of those parts that had undergone the examination of the party in the early part of their present expedition, where they had been much annoyed by ice, and it became another instance of the local existence of these substances."

Of the channel (Gastineau) lying between Douglas island and the mainland, we read (vol. vi. p. 20), "About three leagues up this arm is a small islet nearly in mid-channel. This afforded another instance of the partial existence of the ice, which here entirely blocked up this arm." And again, on p. 25, when returning from Barlow's cove, down Stephens passage, "The point on which the northern village is situated was found to be, as had before been conjectured, the west point of entrance into the narrow icy arm (Gastineau). . . . The channel between this island and the mainland, being rendered by the ice impassable, the boats were steered over to the southern shore for protection against the south-east wind." At the present time ice is occasionally drifted into this channel from Taku inlet, but certainly not to the extent described by Vancouver. More must then have been discharged from Taku inlet, and possibly some from the Mendenhall at the west entrance, which now, however, does not reach tide-water.

Of Taku inlet Vancouver says (vol. vi. p. 26, August, 1794), "in which the great quantity of floating ice, with a strong northerly wind against them, so retarded their progress that a passage was with great difficulty effected. . . . From the shore of this basin" (north of Taku point) "a compact body of ice extended some distance nearly all round. . . . From the rugged gullies in their sides were projected immense bodies of ice that reached perpendicularly to the surface of the water in the basin, which admitted of no landing-place for the boats, but exhibited as dreary and inhospitable an aspect as the imagination can possibly suggest."

LOOKING NORTHWARD OF LITUYU BAY, SHOWING ONE ICE-FRONT.

At the present time there is only one glacier (Foster) discharging directly into the sea, the others having receded, and the gullies are not now so generally filled with ice.

Coming further south; of Holkham bay we find (vol. vi. p. 29, August, 1794), "Much floating ice was seen within the islands" (near the middle at the entrance of the bay). Little or no ice is found there now. In the neighbouring Tracy arm and Endicott arm quite a quantity of small floes may be met, and occasionally pieces are floated out into Holkham bay and Stephens passage. The inference is, therefore, for a diminution. These two arms show unmistakable signs, by their bare marked rock walls, of recent recession.

Sir George Simpson, writing of the same neighbourhood in September, 1841, says, in his 'Journey Round the World,' vol. i. p. 213, "Next

morning we passed through Wrangell straits and Prince Frederick's sound, respectively 22 and 57 miles long, and halted for the night at the entrance of Stephens passage. The valleys were lined with glaciers down to the water's edge; and the pieces that had broken off during the season had filled the channels and straits with fields and masses of ice, through which the vessel could scarcely force her way. Starting again at five in the morning, with a foul wind and thick fog, we ran through Stephens passage; and, when the mist cleared sufficiently for the purpose, the land on either side displayed to us mountains rising abruptly from the sea, and bearing a glacier in their every ravine. Earlier in the season these glaciers would have been concealed by the snow, but now they showed a surface of green ice."

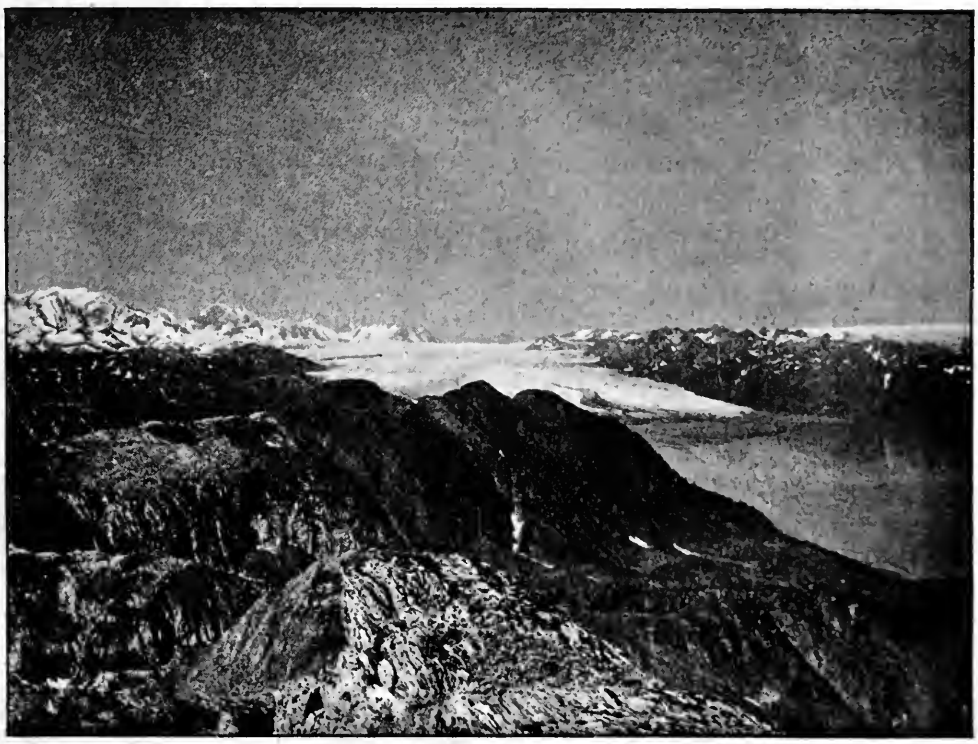
This latter description indicates a great diminution of the glaciers in fifty years, *i.e.* subsequent to 1841, and in the quantity of floating ice encountered in Stephens passage, where now only an occasional floe is seen. Simpson speaks of Gastineau channel, already referred to, as being "generally obstructed by ice."

The vicinity of the Horn cliffs, proceeding south-easterly down Frederick sound, is described by Vancouver, vol. vi. pp. 31, 32 (August, 1794): "A few miles to the south of this margin the mountains extended to the water-side, where a part of them presented an uncommonly awful appearance, rising with an inclination towards the water to a vast height, loaded with an immense quantity of snow and ice, and overhanging their base, which seemed to be insufficient to bear the ponderous fabric it sustained, and rendered the view of the passage beneath it horribly magnificent. Soon after passing this very remarkable promontory, the arm of the sea over which it hangs appeared to be entirely enclosed by a beach, extending all round the head of it; at the south-east extremity was a large body of ice, formed in a gully between the mountains that approach the water-side, from whence much broken ice seemed to have fallen and had entirely covered the surface of the water in that direction."

From the latter part of the above, it would appear that Whidbey was near the mouth of the present Le Conte bay, into which discharges the Le Conte glacier, the most southerly (lat. 56° 49′) at present of living glaciers on the continental shore, but the bay seems to have been filled by the glacier, for no bay is shown (on Vancouver's chart) which is now 6 miles deep. It may be stated that the position given for the ice-front of the Le Conte glacier by the United States Coast Survey, and that made some years later (1893) by us, show a recession of fully half a mile.*

* The definite year in which the United States survey was made is not at the moment known to the writer, but it was probably in the later eighties; hence the exact interval cannot be given. Le Conte bay is not mentioned in the United States Alaska Coast Pilot for 1883, but is given in the one of 1891.

Again referring to Vancouver (vol. vi. p. 34), "Mr. Whidbey observes that in no instance during his researches, either in the several branches of Prince William sound, or in the course of his present excursion, did he find any immense bodies of ice on the islands; all those which he had seen on shore were in the gullies or valleys of the connected chain of lofty mountains so frequently mentioned, and which chiefly constituted the continental shore-line from Cook's inlet to this station; though in different places these mountains are at different distances from the seaside. He likewise observes that all the islands, or groups of islands, were of a moderate height, when compared with the stupendous mountains that compose the continental boundary, and



BRADY GLACIER, TAYLOR BAY.

were still seen to continue in a south-eastern direction from this shallow passage, whilst the land to the westward assumed a more moderate height, was free from snow, and produced a forest of lofty pine trees."

The conclusions arrived at are, that the glaciers eastward of Glacier bay have all diminished since Vancouver's time, *i.e.* within the past hundred years. This does not exclude the fact that some dead glaciers may have and have advanced (*e.g.* the Patterson) for a year or so, due to heavy precipitation and accumulation of snow on the *névé*. The mere fact of recession must have tended to raise the average temperature of the area, and thereby still more hasten recession.

There are no meteorological data for that region covering the period

under discussion that might lend their aid in determining the reasons for the variation of the glaciers. Besides the effect of meteorological conditions, we must not lose sight of those due to physiographic changes.

With reference to the encroachment of the ocean and subsidence of the land, Vancouver writes (vol. vi. pp. 53, 54), ". . . He" (Whidbey) "also states that in his last two excursions" (between Cape Spencer and foot of Frederick sound) "several places were seen where the ocean was evidently encroaching very rapidly on the land, and that the low borders extending from the base of the mountains to the seaside had, at no very remote period of time, produced tall and stately timber, as many of their dead trunks were found standing erect, and still rooted fast in the ground in different stages of decay, those being the most perfect that had been the least subject to the influence of the salt water, by which they were surrounded on every tide; such had been the encroachment of the ocean on these shores, that the shorter stumps in some instances at low-water mark were even with or below the surface of the sea. This same appearance has been noticed before in Fort Chalmers, and on this occasion Mr. Whidbey quotes other instances of similar encroachment, not only in Prince William sound, but also in Cook's inlet."

Probably nowhere on the earth are better opportunities afforded for the study of living and dead glaciers than on the north-west continental shore of America. Within recent years the region has become easily accessible, and with the accurate delimitation of the shores and the position of the glaciers in 1893 and 1894, future surveys of the latter will furnish accurate data for the study of glacial motion.

It is desirable that future investigators leave readily recognizable marks near the ice-front (as was done by the writer in the survey of the Baird in 1894, with white lead on the adjoining bare rock wall), as such are preferable for the determination of the smaller fluctuations of the glacier. Whatever methods of measurement and survey are used, it cannot be too strongly recommended that photographs be taken with a camera of fixed and known focal length from a properly oriented base-line. The study of the motion of glaciers will then be reduced to an exact science.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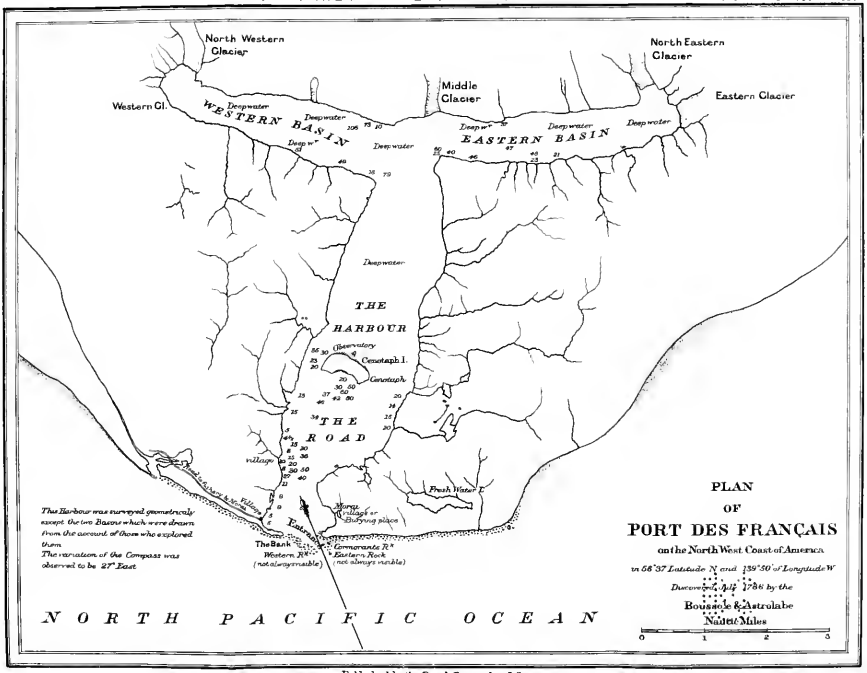

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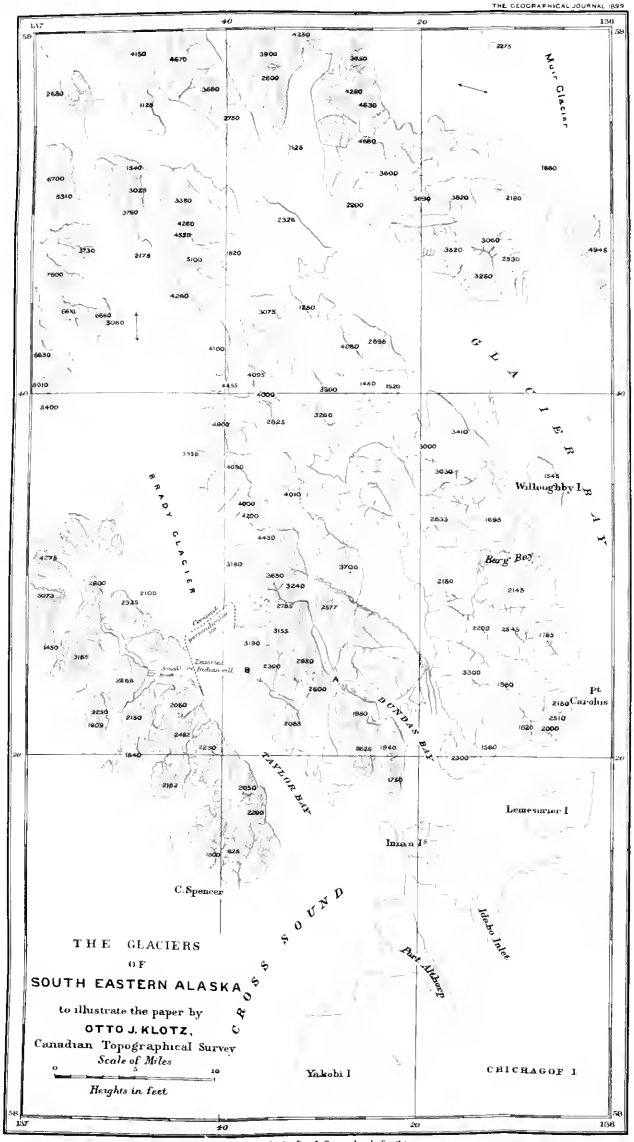

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